Abstract

Separation Management with Detect-and-Avoid in Urban U-Space

Nagel, Enno
Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) , Institute of Flight Guidance, enno.nagel@dlr.de

To integrate large numbers of small unmanned aircraft systems (sUAS) into the complex, obstacle-rich airspace found over modern cities, we adopt a two-tiered separation management approach under Europe's U-Space framework.
Before any flight takes off, a strategic service computes and assigns each sUAS to one of two complementary airspace structures.
First, Corridors are established as one-way, tube-shaped routes at fixed altitude bands (e.g. 500 ft or 600 ft above ground level) with explicit minimum and maximum speed constraints;
these "drone highways" are optimized to carry high-speed, long-distance traffic between urban nodes with minimal conflict potential.
Second, Segments are provided as flexible, free-routing zones in which aircraft are not confined to pre-planned tracks but must instead execute their own Detect-and-Avoid (DAA) maneuvers in real time.
This dual-structure design ensures that routine, predictable traffic benefits from tight geometric control, while irregular or non-nominal flights (e.g. emergency response, wind-diverted trajectories, or multi-drone inspections) can safely disperse into more open, self-managed airspace when needed.

Once airborne, tactical separation is enforced through a robust multisensor DAA fusion engine that combines both cooperative and non-cooperative data streams.
Cooperative information-Remote ID broadcasts per ASTM F3411/EASA prEN 4709-002 and ADS-L (lightweight Air Data System) messages carrying identity, position, and intent-provides a persistent "friendly picture", while non-cooperative sensors (Frequency-Modulated Continuous Wave radar for all-weather range and velocity, infrared cameras for heat-signature detection in low light, and high-resolution optoelectric stereo cameras for fine classification and localization) fill in the rest of the environment.
An adaptive Kalman-filter framework continuously tunes sensor error covariances using pre-flight calibration and in-flight innovation residuals, applies Mahalanobis gating to reject outliers, and weights each measurement inversely to its estimated signal to noise ratio and latency.
By dynamically adjusting these fusion parameters to urban clutter, multipath, and visibility conditions, the system maintains high detection confidence and minimal latency in dense, obstacle-laden airspace.

To size both corridors and buffer zones in these structures, we derive performance-based separation minima tailored to each drone's flight capabilities and onboard DAA performance.
For every aircraft type, we gather its maximum climb and descent rates, turn radii, maximum acceleration/deceleration limits, sensors' field of view and update rate, and processing latency.
We then calculate the minimum horizontal and vertical distances required to guarantee an evasive turn, altitude change, or speed adjustment under worst-case reaction times.
These values define both the width and vertical stacking of one-way Corridors and the maximum density of free-routing Segments, ensuring that even the least capable sUAS retains sufficient maneuvering room to avoid conflicts.

Using AirES, DLR's aircraft encounter simulator, we systematically compute, for each ordered pair of drone models and for discrete reaction-time intervals (e.g. 2, 3, 4 s), the minimal safety buffer needed to avoid a collision via one of three fixed avoidance maneuvers:
horizontal turn, vertical climb/descent, or speed change (brake or accelerate).
Each simulation assesses the worst-case initial geometry and relative velocities typical of urban operations, producing a matrix of separation distances.
To derive a global corridor separation standard, we take the maximum over all drone-pair combinations of the smallest distance across the three avoidance modes.

Finally, for real-time conflict resolution we compare two complementary approaches.
ACAS sXu-a variant of the FAA's ACAS-X adapted for small drones-employs dynamic scaling of advisory sensitivity and response thresholds based on current local traffic density, altitude, and aircraft performance.
It computes an optimal avoidance trajectory (e.g. "climb at X ft/min") via pre-computed dynamic-programming tables.
While ACAS sXu yields tighter separation minima by optimizing every maneuver, the AirES approach offers computational simplicity and faster lookup.
In a hybrid implementation, sUAS could use ACAS sXu for critical, precision avoidance and fall back on the AirES tables as a computationally lightweight safety net.

Biography

Speaker Given Name

Studies and PhD in Mathematics at the University of Münster, since 2024 researcher on flight guidance of unmanned air systems at the DLR